CRD report

News from the LBNL Computational Research Division October 2006

CRD Astrophysicist's Algorithm Leads to Super-massive Supernova Discovery

A group of scientists affiliated with the SuperNova Legacy Survey (SNLS) have found startling evidence that there is more than one kind of Type Ia supernova, a class of exploding stars which until now has been regarded as essentially uniform in all important respects. Supernova SNLS-03D3bb is more than twice as bright as most Type Ia supernovae but has much less kinetic energy, and appears to be 1.5 times as massive as a typical Type Ia.

The lead authors of the report, which appeared in the Sept. 21, 2006 issue of Nature, include Andrew Howell, formerly of the Physics Division at Berkeley Lab, and now at the University of Toronto, and Peter Nugent, an astrophysicist in CRD. Nugent's research enabled scientists to distinguish SNLS-03D3bb from previously known Type Ia supernovae. While working at NERSC, Nugent developed an algorithm that could take a handful of photometric data points early in the evolution of a candidate supernova, positively identify it as a Type Ia, and accurately predict its time of maximum brightness.

The report's other lead authors are Mark Sullivan of the University of Toronto and Richard Ellis of the California Institute of Technology. These and many of the other authors of the Nature paper are members of the Supernova Cosmology Project based at Berkeley Lab.

Because almost all Type Ia supernovae found so far are not only remarkably bright but remarkably uniform in their brightness, they are regarded as the best astronomical "standard candles" for measurement across cosmological distances. In 1998, after observations of many distant Type Ia supernovae, the Supernova Cosmology Project and the rival High-Z Supernova Search Team announced their discovery that the expansion of the universe is accelerating — a finding that would soon be attributed to the unknown something called dark energy, which fills the universe and opposes the mutual gravitational attraction of matter.

"Type Ia supernovae are thought to be reliable distance indicators because they have a

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Credit: Canada-France-Hawaii Telescope Legacy Survey/A. Howell

Brilliant find in the sky: Supernova SNLS-03D3bb (lower right quadrant) stands out among its fellow Type Ia supernovae.

Internet Research Paper Wins SIGCOMM Award

Working in the fast-paced field of Internet research, Vern Paxson of CRD's Distributed Systems Department has won the inaugural Test of Time Award from the Special Interest Group on Data Communications (SIGCOMM) of the Association for Computing Machinery (ACM).

Vern Paxson

The new award, announced in the current issue of Computer Communication Review (CCR), recognizes research from 10 to 12 years ago that marked a milestone in its field and continues to provide insight today.

SIGCOMM recognized Paxson for his 1996 paper developing a measurement methodology to effectively collect and assess the performance of the Internet, even though the data came from stations sitting at the edge — instead of the center — of the network.

"Vern's insights into the inner workings of and traffic on the Internet in this early paper were truly ground breaking," said Deb Agarwal, head of CRD's Distributed Systems Department. "We are very proud to have his work recognized by this Test of Time award."

A CCR editorial about the award noted that Paxson carried out his research at a time when measuring the network's performance had become increasingly difficult for scientists. The growing number of competing Internet service providers and privacy worries had created roadblocks for researchers interested in accessing data about the network's core.

It was in this context that Paxson was pursuing his Ph.D. dissertation research at UC Berkeley while working as a member of the Lab's Network Research Group (NRG). His overall topic was "What sort of performance do Internet transfers achieve, and why?" To

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Study Links Human Activities to Warmer Oceans, Stronger Hurricanes

New research shows that rising sea surface temperatures (SSTs) in hurricane breeding grounds of the Atlantic and Pacific Oceans are unlikely to be purely natural in origin. These findings, according to a team of researchers including Michael Wehner of CRD's Scientific Computing Group, complement earlier work that uncovered compelling scientific evidence of a link between warming SSTs and increases in hurricane intensity.

Previous studies to understand the causes of SST changes have focused on temperature changes averaged over very large ocean areas — such as the entire Atlantic or Pacific basins. The new research specifically targets SST changes in much smaller hurricane formation regions.

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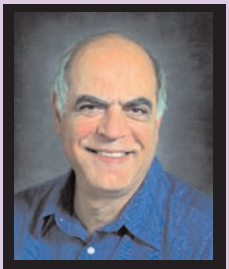
LBNL to Lead Five Projects Under SciDAC-2

Berkeley Lab's expertise and leadership in computational science was recognized and rewarded recently when DOE Under Secretary for Science Ray Orbach announced the second round of projects under the Scientific Discovery through Advanced Computing (SciDAC) program, to be funded at $60 million per year.

Wes Bethel

Phillip Colella

The SciDAC program, launched in 2001, brings together some of the nation's top researchers at national laboratories and universities to create the software and infrastructure needed to help scientists effectively utilize the next generation of supercomputers for tackling the toughest scientific challenges — some of which can only be studied through high performance computation and simulation. A hallmark of the program is collaboration between scientific application teams and groups working to develop software tools for improving the scientific codes.



Arie Shoshani

David Skinner

Of the 30 projects announced, Berkeley Lab researchers will lead five and play key roles in nine others. The LBNL projects, most of which are five years in length, will be funded at about $10 million annually.

"This is very exciting and very welcome news in that all of the proposals were rigorously reviewed and we were selected to contribute in significant ways to nearly half of the projects," said Associate Lab Director for Computing Sciences Horst Simon. "What is especially gratifying is that funding at LBNL has increased compared to SciDAC-1 and our contributions were such that DOE felt the work should continue. When you look at the big picture, it's clear that Berkeley Lab is one of the foremost institutions for computational science."

The Applied Partial Differential Equations Center established under the first round of SciDAC develops simulation tools for solving multi-scale and multi-physics problems. Their algorithms have been used to create laboratory-scale turbulent flame simulations, study

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Paxson

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address this question in a sound fashion required judicious application of the right tools, including the tcpdump and traceroute utilities developed by NRG's Van Jacobson (and now ubiquitously employed in network measurement) and Wolff's PASTA principle for how to conduct a series of measurements in order to estimate average properties in an unbiased manner.

Paxson gathered and produced meaningful analysis of 40,000 route measurements conducted in a "mesh" across 37 Internet sites. The work, published in the annual SIGCOMM conference in a paper titled "End-to-End Routing Behavior in the Internet," sought to answer questions about the network's stability, symmetry, infrastructure failures, temporary outages, and routing pathologies.

Of his award, Paxson said, "It's a delight for the work to be recognized in this fashion. In some ways, the whole effort was born out of desperation: it was clear to me that if I tried to conduct my measurements just from Berkeley to a few other places, there was no way I could honestly say I had a view of how the Internet actually works in general. Out of this concern emerged the idea of conducting measurements from many different locations — much easier said than done! And once I conducted and analyzed the measurements, they proved very sobering in terms of just how varied the network performance experienced at different locations ranged. But it was also thrilling to finally obtain a sort of 'big picture' view that had been elusive until then. To this end, I am very grateful to the many volunteers who helped facilitate my measurements; and particularly to Van Jacobson, the head of NRG at the time, and my NRG colleague Sally Floyd, who were both instrumental to the success of the entire effort."

The work yielded surprising results and common themes, one of which was the wide range of routing behavior observed by various sites. In his paper, Paxson wrote that the findings confirmed the belief that there is no "typical" Internet site or path. "But we believe the scope of our measurements gives us a solid understanding of the breadth of behavior we might expect to encounter — and how, from an end-point's view, routing in the Internet actually works." A subsequent journal version of the paper published in 1997 in IEEE/ACM Transactions on Networking was awarded the IEEE Communications Society William R. Bennett Prize Paper Award.

Paxson's research ignited a renewed interest in network measurement study and contributed a few years later to his co-founding of the ACM Internet Measurement Conference. Paxson also concurrently developed Bro, an open source, UNIX-based network intrusion detection system. Used continuously at Berkeley Lab since 1996, Bro monitors and analyzes the network traffic to detect and block malicious activity.

You can find out more about what Paxson uncovered in his 1996 research at http://www.sigcomm.org/ccr/drupal/files/p43-paxson.pdf.

CRD Report

CRD Report is published every other month, highlighting recent achievements by staff members in Berkeley Lab's Computational Research Division. Distributed via email and posted on the Web at http://crd.lbl.gov/DOEresources, CRD Report may be freely distributed. CRD Report is edited by Ucilia Wang, UWang@lbl.gov, 510-495-2402.

Hurricanes

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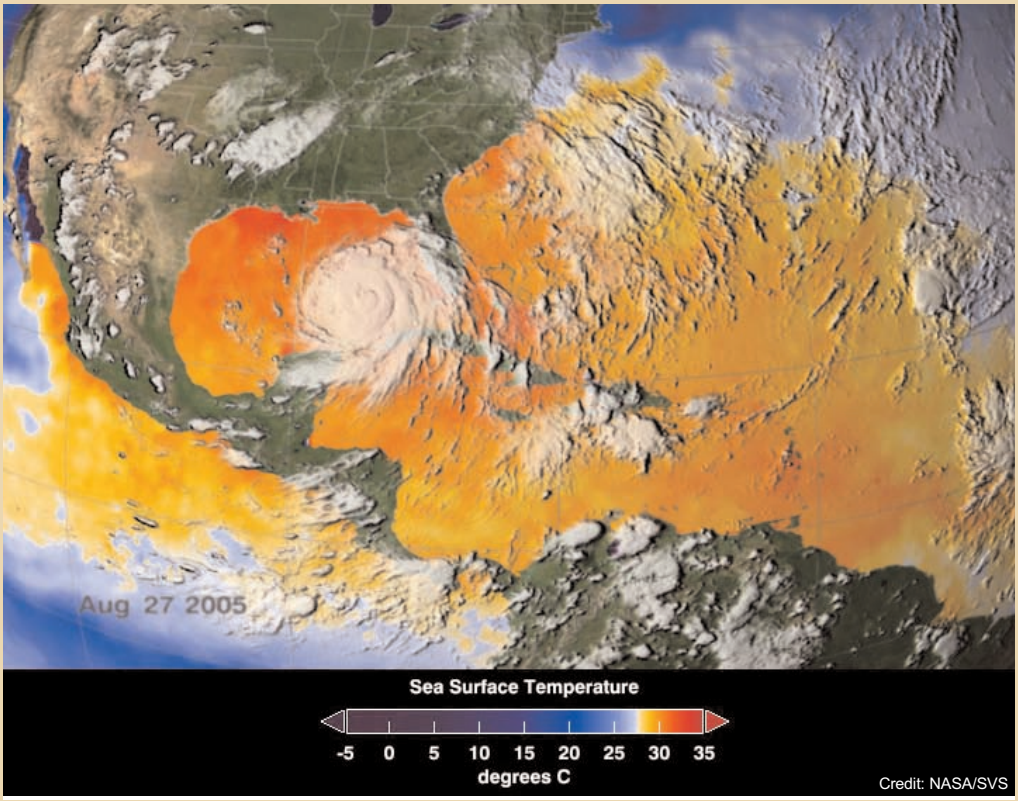
Using 22 different computer models of the climate system, atmospheric scientists from 11 research centers have shown that the warming of the tropical Atlantic and Pacific oceans over the last century is directly linked to human activities.

"We've used virtually all the world's climate models to study the causes of SST changes in hurricane formation regions," said Benjamin Santer of Lawrence Livermore National Laboratory's Program for Climate Model Diagnosis and Intercomparison, lead author of a paper describing the research that appeared online recently in the Proceedings of the National Academy of Sciences. "The bottom line is that natural processes alone simply cannot explain the observed SST increases in these hurricane breeding grounds. The best explanation for these changes has to include a large human influence."

For the period 1906–2005, the researchers found an 84 percent chance that external forcing (such as human-caused increases in greenhouse gases, ozone and various aerosol particles) accounts for at least 67 percent of the observed rise in SSTs in the Atlantic and Pacific hurricane formation regions. In both regions, human-caused increases in greenhouse gases were found to be the main driver of the 20th century warming of SSTs.

"It's safe to say that even the conservative estimates of the 21st century will see significantly larger increases in the temperature in this region that we examined than we've already seen," Wehner told the Contra Costa Times. "You ain't seen nothing yet." Hurricanes are complex phenomena and are influenced by a variety of physical factors such as SST, wind shear, moisture availability and atmospheric stability. The increasing SSTs in the Atlantic and Pacific hurricane formation regions isn't the sole cause of hurricane intensity, but is likely to be one of the most important influences on hurricane strength.



This image depicts a three-day average of actual sea surface temperatures (SSTs) for the Caribbean Sea and the Atlantic Ocean, from August 25–27, 2005. The yellow, orange or red area represents 82 degrees Fahrenheit or above, which is what a hurricane needs to increase its strength.

Using the computer models, Wehner created scenarios involving different levels of carbon emissions and generated ocean temperature forecast. The result: Curbing the rise of SSTs will take a while, even if humans stop emitting greenhouse gases right away. If no actions are taken to curb emissions, then the ocean temperature could rise as much as nine degrees by the end of the century and help create more catastrophic natural disasters.

The team also included researchers from the National Center for Atmospheric Research, the University of California, Merced, the Scripps Institution of Oceanography, the University of Hamburg in Germany, the Climatic Research Unit and Manchester University in the United Kingdom, the NASA/Goddard Institute for Space Studies and the National Oceanic and Atmospheric Administration's National Climatic Data Center.

By Anne M. Stark, LLNL Communications Department.

Supernova

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standard amount of fuel — the carbon and oxygen in a white dwarf star — and they have a uniform trigger," Nugent said. "They are predicted to explode when the mass of the white dwarf nears the Chandrasekhar mass, which is about 1.4 times the mass of our sun. The fact that SNLS-03D3bb is well over that mass kind of opens up a Pandora's box."

Classification of supernova types is based on their spectra. Type Ia spectra have no hydrogen lines but do have silicon absorption lines, a clue to the chemistry of their explosions. The white dwarf progenitors of Type Ia supernovae, typically about two-thirds the mass of the sun, are thought to accrete additional mass from a binary companion until they approach the Chandrasekhar limit. Increasing pressure causes the carbon and oxygen in the center of the star to fuse, producing the elements up to nickel on the periodic table. The energy released in this process blows the star to pieces in a titanic thermonuclear explosion.

Why is SNLS-03D3bb brighter than the typical Type Ia supernovae? One clue was the elements needed to produce the extra brightness. "A Type Ia of normal brightness makes about 60 percent of a solar mass worth of nickel-56, the rest being other elements. But SNLS-03D3bb is more than twice as bright as normal; it must have more than twice as much nickel-56," Nugent said. "The only way to get that is with a progenitor that's 50 per-

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SciDAC

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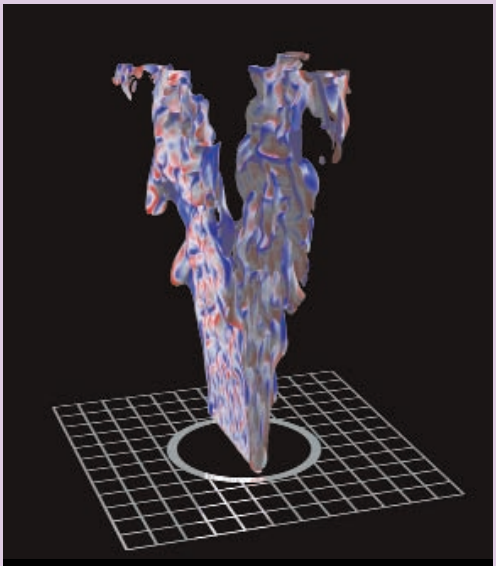
refueling of fusion reactors and model combustion in supernovae. The center will continue under the leadership of Phil Colella of CRD.

The Scientific Data Management Center will also be continued under SciDAC-2. Led by Arie Shoshani of CRD, the center develops tools to improve the sharing and analysis of massive amounts of data from both simulations and experiments. One of its key accomplishments under the first round of SciDAC was the development of FastBit, an indexing method which enables data searches up to 10 times faster than commercial search tools.

A new center created under SciDAC-2 will be the Visualization and Analytics Center for Enabling Technologies (VACET), led by CRD's Wes Bethel, which will develop tools to help scientists effectively understand and make use of the growing amounts of data. The VACET center will respond directly to this challenge by adapting, extending, creating when necessary, and deploying technologies that will enable our scientific stakeholders to visualize and understand the wealth of data now available to them.

Another new projected centered at Berkeley Lab will be the SciDAC Outreach Center, to be led by David Skinner. Located at NERSC, the center will provide information and services that support SciDAC outreach, training, and research objectives. Additionally, the Center will gather data to understand the needs of the HPC community to identify workshops, summer schools, institutes and research topics to meet those needs.

Several new scientific domains, including biology and underground transport, were added to SciDAC as part of the second round. Steven Brenner of Physical Biosciences, along with Michael Jordan of UC Berkeley, are co-leaders of the Robust and Precise Gene Function Predictions on a Genomic Scale project. This project will refine algorithms to automate a process for predicting the functions of proteins in a family of microbes. By better understanding the function of these proteins, DOE hopes to harness the potential of microbial communities for the remediation of contaminated sites, development of smart sensors, and the biogeneration of hydrogen and ethanol.



Using algorithms developed under SciDAC, Berkeley Lab applied mathematicians worked with combustion scientists in EETD to create this 3D simulation of a laboratory-scale flame consisting of 19 chemical species and 84 fundamental chemical reactions.

Berkeley Lab Computing Sciences staff in CRD and the NERSC Division will also serve as co-investigators in nine other SciDAC projects addressing research issues in astrophysics, climate change, sharing and managing massive amounts of scientific data, developing software for next-generation supercomputers, developing new software tools for studying complex problems, and assessing and improving the performance of large-scale computers.

More information about the SciDAC program can be found at www.scidac.gov.

Supernova

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cent more massive than the Chandrasekhar mass."

Moreover, in most brighter supernovae, the matter ejected from the explosion travels at a higher velocity. But the ejecta of SNLS-03D3bb were unusually slow. The velocity of supernova ejecta depends on the kinetic energy released in the explosion, which is the difference between the energy released in thermonuclear burning minus the binding energy that acts to hold the star together.

It's possible that a very rapidly spinning star could be more massive. It's also possible that two white dwarfs, with a combined mass well over the Chandrasekhar limit, could collide and explode.

In old, dead galaxies even the biggest stars are small, Nugent explains. The only kinds of Type Ia supernovae possible in these galaxies are likely to be the binary-system, mass-accreting, Chandrasekhar-mass type. But young star-forming galaxies produce massive objects and could be rich in white-dwarf plus white-dwarf binary systems, so-called "double-degenerate" systems.

It was partly in hopes of developing a quick and dependable way to identify candidate Type Ia supernovae that Nugent and coauthor Richard Ellis initially approached Sullivan and other members of the SNLS, with its large database of supernovae. One of the first Type Ia's studied this way turned out to be SNLS-03D3bb itself.

Nugent regards the discovery of the first demonstrable super-Chandrasekhar supernova as an exciting prospect: "For the first time since 1993" — when the brightness versus light-curve shape relationship was developed — "we now have a strong direction to look for the next parameter that describes the brightness of a Type Ia supernova. This search may lead us to a much better understanding of their progenitors, and the systematics of using them as cosmological probes."

By Paul Preuss, LBNL Communications Department.

Read the press release about this supernova research breakthrough at http://www.lbl.gov/Science-Articles/Archive/Phys-weird-supernova.html.